OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
1400 DEFENSE PENTAGON
WASHINGTON, DC 20301-1400

PUBLIC AFFAIRS

JUN 24 1997

Ref: 97-F-0956

Ms. Cheryl Welsh
[redacted]

Dear Ms. Welsh:

This responds to your May 12, 1997,, Freedom of Information Act (FOIA) request addressed to the Defense Advanced Research Projects Agency (DARPA). Our June 16, 1997, interim response refers.

The enclosed document is provided by DARPA as responsive to your request. Mr. R. H. Register, Deputy Director for Management, DARPA, an Initial Denial Authority, has determined that the deleted portion must be withheld because its release would constitute a clearly unwarranted invasion of the personal privacy of an individual. Accordingly, this information has been withheld pursuant to Title 5 USC § 552 (b)(6).

You have a right to appeal Mr. Register's decision to withhold portions of these records. Any such appeal should offer justification to support an additional release, and must be received in this Directorate within 60 calendar days of this letter's date. Our address is: Directorate for Freedom of Information and Security Review, Room 2C757, 1400 Defense Pentagon, Washington, DC 20301-1400.

Due to the size and complexity of the Department of Defense (DoD), there is no central repository for all DoD records. This Directorate is responsible for responding to requests for records of the components of the Office of the Secretary of Defense and the Joint Staff (OSD/JS). The several components of the DoD, including the military departments and separate defense agencies, operate their own Freedom of Information offices to respond to requests for records for which they are responsible. These procedures are provided in DoD Regulation 5400.7-R, as published at 32 CFR 286.

DARPA advises that records possibly responsive to your request may be under the cognizance of the Office of Naval Research (ONR). Accordingly, your request has been referred to ONR for processing and direct response to you at the following address:

RR

#877

Office of Naval Research
Ballston Centre
Tower One
800 N. Quincy St. Room 207
Arlington, VA 22217-5660

Sincerely,

A. H. Passarella
Director
Freedom of Information
and Security Review

Enclosures:
As stated

20714

CYBERNETICS TECHNOLOGY DIVISION

PROGRAM COMPLETION REPORT

Program Title: Close-Coupled Man/Machine Systems Research (Biocybernetics)

Program Element(s): 61101E, 62709E

ARPA Order No(s): 3053, 3294, 3306, 3330, 3510

DARPA Agent: ONR, Directorate of Research Programs, Psychological Sciences Division

DARPA Technical Agent Key Program Manager and Phone Number: ONR - Don Woodward/696-4257

Prepared by:

Judith Ayres Daly
Program Manager
Date 1/30/81

Approved:

Craig Fields
Assistant Director
for Cybernetics Technology
Date 1/30/81

Reviewed by:

Ray E. Chapman
Director, Program Management
Date 4/23/81

Approved:

Carl F Ronney for Robert R. Fossum
Director, DARPA
Date 27 April '81

#877

Program Title: Biocybernetics

Program Objectives and Technical Need

The Biocybernetics Program was launched in FY74. A preliminary meeting of the Principal Investigators was held in 1973. The Program's purpose is well expressed in its initial title "Close-Coupled Man/Machine Systems."

The Program's goal was to develop new communication links between man and computer-assisted systems. These links, it was hoped, would enhance a man-machine system ability to perform its goals. This effort was seen as complementary to the main thrust of the development of computer applications in man/machine systems. In the main the traditional goal has been the development of tools that can take over some of the operators' functions by providing substitutes that can perform a large variety of functions. This "prosthetic" approach includes a diversity of developments, from the development of power steering mechanisms for efficient control of mechanical devices to the implementation of sophisticated Artificial Intelligence. The Biocybernetics Program was based on the presumption that no matter how wide spread, and successful, the application of computer-based prosthetic devices the operator will not be eliminated. Therefore, in all such systems, success will ultimately depend on the interaction between man and the mechanical contrivances which surround him in the man/machine system. Interaction between man and machine implies two-sided communication. There is, however, a gross asymmetry in the bandwidth of the communication from the machine to the operator and the bandwidth from the operator to the machine. The machine can use any number of displays and at very marginal cost it can saturate these with enormous masses of data. The communication from the operator to the machine, on the other hand, is restricted to a small number of limited capacity communication channels, the use of most of which is constrained by the capacities of the operator and by the fact that competition in the performance of tasks is detrimental to overall performance. The Biocybernetics Program, therefore, attempted to explore the possibility of innovative uses of machine technology for increased human performance. Some of the topics to be examined were:

1. Direct man/machine communications through bio-electric signals, instead of traditional I/O or voice recognition and speech analysis for enhanced command and control.

   (a) Could the brain make advantageous use of order of magnitude or greater increase in rate of information flow?

   (b) To what extent can the brain act as time-shared or parallel processor?

   (c) How far can non-invasive interfaces lead? Research and end products presumably were to involve only intact humans.

   (d) Could same technology be applied to similar enhancement of man/man communications, perhaps by a central machine processor?

2. Machine monitoring of individuals in groups to assess continuously momentary states of such attributes and functions as vigilance, fatigue, emotional state, decision making, perception and general cognitive

ability.

When the Biocybernetics Program began, the relevant data base consisted of the entire body of Psychophysiological literature. This literature is concerned with manifestations of physiological activity that can be recorded from the intact human and with inferences that can be made from such recordings about psychological states and events. While this work provided a useful substrate for the Biocybernetics Program and identified in a useful fashion the broadening areas of research, the Program treaded largely virgin territory because (a) electrophysiological research was concerned primarily with the recording and analysis of physiological responses that seemed particularly sensitive to the changes in the arousal state of the subject rather than with specific cognitive activity. (b) The technology of psychophysiology did not permit ready application of the on-line, real time, analytical techniques that were necessary conditions for the implementation of closely coupled man/machine systems.

Program Description and Evolution

In general, the program plan was designed to:

1. Identify psychophysiological signals which are promising candidates for serving as biocybernetics communication channels.

2. Implement, on an experimental basis in laboratory circumstances, models of biocybernetics communication channels using, in several different laboratories, different psychophysiological indicators.

3. Develop the analytical and computer techniques necessary for extending the power of these biocybernetic communication channels so that real time, on-line, closed loop implementation could become feasible.

4. Through evaluation of the experimental laboratory research, choose one of several psychophysiological signals and try to implement a realistic, closed loop, biocybernetics channel.

5. Identify DOD efforts in which a need for biocybernetics communication channels is most clearly realized and try to transfer the achievements of the program into implementations within the DOD context.

   Specifically, major efforts in the program and associated technical approaches were:

   (a) Harvard University, "The Use of Electromyography to Implement a Silent, Fast Typewriter." The purpose of this project was to develop a technique for increasing the speed with which individuals can input text into a computer system. The intent was to develop a communication device, utilizing submovement EMG from the finger/thumb muscles that have been associated with alphabetic stimuli.

   (b) University of California at Los Angeles, "The Application of Pupillometry Towards the Estimation of Momentary Information Processing Load or Mental Effort Associated with Various Functions and Tasks." The diameter of the pupil can be measured using

photographic techniques and application of computer processing to the video signal recorded from the pupil. Small changes in the diameter of the pupil are induced by the imposition of processing tasks on the subject. The amplitude of the pupillary response seems to be a good measure of the amount of effort required by the task. The UCLA project intended to validate these claims and to develop techniques that will provide the basis for computer identification of momentary shifts in cognitive function.

(c) University of California at Los Angeles, "Direct Brain-Computer Coupling Via Brain Responses." This project, as several of the others listed below, focused on the study of event-related brain potentials. This psychophysiological channel became amenable to study only a few years before the inception of the Biocybernetics Program and its potential utility in the analysis of cognitive and sensory responses became evident just as the program was beginning. The UCLA effort focused primarily on the utilization of early, exogenous or sensory, event related brain potentials and their utilization in the biocybernetics communications system. A substantial component of the effort at UCLA was focused on the development of novel data analytic techniques that will permit an on-line, real time utilization of these components. Of particular interest was the degree to which it would be possible to determine which color was used to stimulate a subject and which part of the retina was stimulated at any given time. The use of non-linear, multi-dimensional, statistical techniques was also emphasized.

(d) University of Rochester, "Event-Related Brain Potential Correlates of Stimulus Meaning." This project also focused on event-related brain potentials and was designed essentially to test the hypothesis that the location of specific words in a multi-dimensional mapping of meaning provided by Osgood is reflected by the brain response to the stimulus. It was believed that it would be possible to identify the effective value of stimuli to a subject by a proper analysis of the event-related brain potentials.

(e) University of Illinois, "The Vocabulary of Event-Related Brain Potentials and its Application in the Cockpit and CAI Environment." This project made the following assumptions: (a) In online man-machine systems the rate and amount of data transmitted from the computer to man exceed by several orders of magnitude the rate and amount of data which can be transmitted from man to the computer. (b) Human information processing (HIP) is considerably more extensive than is revealed by overt responses at any instant. (c) Aspects of HIP manifest themselves externally by affecting peripherally recordable signals such as the electroencephalogram. Event-related potentials (ERPs), which can be extracted from the EEG using standard signal averaging procedures, are a particularly powerful manifestation of information processing activities. (d) The ERP consists of a series of components, each representing the activities of neuronal cell populations, each playing some particular role in the sequence of information processing activities. Changes in the amplitude and latency of each of these components are systematically related to changes in the information processing activities which these components manifest. (e) It is possible, using pattern recognition procedures, to detect and

measure these components following a single occurrence of any event once the waveform of the component has been determined. Finally, it was assumed that it will be possible to utilize the data about the operator conveyed by these components as information useful for the optimization of system operation.

(f) Stanford Research Institute, "Inferring Words from Electrical Brain Activity." This project assumed that specific words, when "thought" by the subject, will have distinguishable correlates in the on-going EEG activity recorded from the scalp. Should this prove the case, a clear implementation of a communication channel would result.

(g) Stanford Research Institute, "The Use of Hemispheric Imbalances as an Indication of Cognitive Style and Cognitive Strategy." This project derived from the assumption that there is a complementary specialization of the two hemispheres and that this functional asymmetry can be revealed by EEG recording. It was further assumed that individual variability in the degree of asymmetry reflects a capacity to deploy resources in the service of tasks. The project plan called for the development of procedures for teaching subjects, through biofeedback techniques, to enhance EEG asymmetry. In parallel it was planned to assess the degree to which spontaneous alterations in the degree of asymmetry are functionally relevant.

(h) The Naval Health Research Center, San Diego, CA, "Computer Monitoring of Physiological States to Aid in Maintenance of Effective Human Performance." This was a component of the program in which focus on alertness during prolonged periods of operations was maintained. The hope was that a system could be developed to identify or predict performance lapses from psychophysiological data.

(i) Massachusetts Institute of Technology, "The Utilization of Magnetoencephalography (MEG) as a Biocybernetics Channel." The development of super-conducting conductors made it possible to record the magnetic activity or cortical tissue. This recording system provides a number of advantages over the traditional electroencephalographic recording techniques though at a cost of very expensive and cumbersome electrodes. This project was to determine the utility of the MEG by identifying the information content of the MEG and the manner in which it might differ from the information content of the EEG. Directions for future technological development that would make the technique practical were also to be explored.

(j) Stanford University, "The Combined Utilization of Eye Movement Monitoring with Alpha Analysis for Performance Enhancement." This project, a cooperative effort between Stanford Univeristy and NASA-Ames, was directed toward the enhancement of human learning emphasizing the study of scanning and storing techniques associated with superior recall and recognition.

(k) Scientific Applications Incorporated, Arlington, VA, "The Implementation of a Biocybernetic Channel in Realistic Environments." This effort, which was initiated quite late in the history of this program, was undertaken in order to test some of the

accomplishments of the program achieved in university laboratories within the more realistic setting of DOD projects. The group had two assignments: (1) To survey the DOD environment for promising sites for the application of biocybernetics techniques, and (2) to test the utility of biocybernetics within a message sorting environment.

It should be noted that while all of the above projects have been supported at one time or another within the framework of the Biocybernetics Program, only a small number of these were supported from the inception of the program to its termination. As the program proceeded, several projects were phased out, several projects were greatly expanded, and several projects were added. Furthermore, while the entire program was conceived of as a five-year project, only the project at the University of Illinois was supported for the entire period. This checkered history reflected programmatic, organizational and personnel changes at DARPA. These considerations must be taken into account when evaluating the relative success or failure of this program.

Scientific and Technical Results and Accomplishments

Despite the instability referred to above and the large-scale withdrawal of support from the program at a number of critical junctures, the program has been largely successful in achieving at least a number of its goals. Of particular relevance is the major impact that this program has had on the study of event-related brain potentials and its application to Human Engineering. The major support this program has provided to the study of brain potentials has produced an enormous increment in the understanding of the endogenous components of the human evoked response. The emphasis on real time, on-line analysis has propelled the development of applications of multivariate statistical techniques to single trial analysis of the amplitude and latency of event-related brain potentials. Within this context, the utility of psychophysiological techniques in general, and of event-related brain potentials in particular, within the framework of studies of man/machine interactions has undergone a major change.

These developments came at a time in which traditional techniques for analyzing human performance in man/machine systems are undergoing a crisis. Conventional techniques used for assessing workload and human capacity are widely perceived to be in need of substantial augmentation. The procedures developed within the framework of the Biocybernetics Program seem to match many of the needs that are developing within the Human Engineering community.

Specific accomplishments include:

1. A very detailed understanding of several of the endogenous components of the human evoked response. Particular emphasis has been on the P300 component and associated activities which seem to be a unique response of the system to surprising, task relevant events. The latency of the P300 has proven to be a good measure of categorization time while the amplitude appears to be a useful index of subjective probability assigned to the eliciting events and of the relevance of specific events. These attributes of the P300 make it a useful indicator of the direction of attention of an individual within a complex task and of the

probability which is assigned to environmental events.

2. A detailed analysis of the applicability of several multivariate statistical techniques to event-related potential research has been undertaken within the framework of the program. Both through the activities of several of the investigators and in a number of workshops sponsored by the program, the multivariate problems associated with the analysis of the enormous data masses that are obtained in evoked response experiments and the specific needs induced by the importance of single trial techniques in realistic applications have led to the selection of several procedures and their implementation within the context of closely coupled man/machine systems.

3. Several laboratory examples of closely coupled man/machine systems have been implemented, in particular at the UCLA projects and in the University of Illinois. The University of Illinois, in particular, has been able to develop a small, portable package for the conduct of biocybernetic experiments within fairly complex field environments. The major importance of this accomplishment has been its impact on the transfer of biocybernetic technology to other DOD organizations.

4. Several of the other methodologies that have been evaluated by the program have proven quite promising. In particular, this is true of pupillometry and magnetoencephalography. In neither case has the technique been supported to the point that it could be incorporated in a true laboratory demonstration of closely coupled man/machine systems. However, the basic scientific findings are important and can serve as a substrate for the development of additional biocybernetic channels.

Applications and Considerations for the Future

The Biocybernetics Program has had an important impact on the field of Human Engineering. The concepts underwritten by the program and the findings developed within its framework have been received with considerable interest in the Human Engineering community. As noted above, the attempt has met the contemporary need to develop new paradigms for workload assessment. The most direct evidence of the interest in the program is the fact that support for the research of its major contractor, the University of Illinois' Cognitive Psychophysiology Laboratory, has been transferred to the Air Force, the Office of Naval Research, The Environmental Protection Agency, and the National Aeronautics and Space Administration. Several other DOD agencies are examining with interest the possibility of developing biocybernetically-oriented research programs. Most of the investigators supported by this program are continuing their work with support from DOD and other federal agencies, mostly NSF and HEW. It is difficult to evaluate what would have been the impact of the program had the originally planned levels of support been maintained throughout the life of the program. The liberal and continued support to the University of Illinois has yielded useful results. Had similar support been forthcoming to some of the other projects, it is quite likely that in some at least, major progress would also have been achieved.

The major unfulfilled objective of the Biocybernetic Program has been the active implementation of a closed loop man/machine system within a realistic environment. There are two reasons for this failure. First,

financial constraints necessitated reduction of funding for that phase of the program. Thus no one was in an active position to conduct the evaluation. Second, the actual implementation of a closed circuit biocybernetic channel requires a very substantial increment in investment relative to the modest costs of laboratory research. Such a demonstration at this time would not have yielded scientific results of value commensurate with their costs. It appears that continued laboratory research would provide a higher yield per dollar invested.

An important consideration in evaluating the Biocybernetic Program is the fact that its results can be judged not only in terms of the goals specified for the program in terms of DOD's missions but also in terms of their scientific value. The program has had a major impact on the field of psychophysiology and has brought the interest in the cognitive related components of the human ERP to a depth and breadth that would not have been achieved without the program's support. A perusal of the bibliography in the following section will indicate that a large number of publications have appeared in the open, refereed, scientific literature. This fact attests to the scientific quality of the program.

Program Impact and Assessment of Technology Developed:

The program impact on its primary target, the Human Engineering community, can perhaps be assessed best by considering the proceedings of a workshop managed by McDonnell-Douglas for CTO, that was held in Chicago, Illinois, in 1978. The workshop convened many representatives of the DOD research and development community with many of the investigators supported by this program. The intent was to present the program's results to the field, to evaluate these results and to foster, where appropriate, collaborative research. The workshop proved a success. The details are presented in the following reports:

a) Gomer, F. E., Beideman, L., & Levin, S. The application of biocybernetic techniques to entrance pilot performance during tactical missions. McDonnell Douglas Corporation Report #E-2046, 1979.

b) Gomer, F. E. (Ed.), Biocybernetic Applications for Military Systems. Proceedings of the DARPA Conference, Chicago, 1978. St. Louis: McDonnell Douglas Corporation, in press.

c) Gomer, F. E., & Youngling, E. W. Electrophysiological applications to human factors problems in military settings. Human Factors Society Bulletin, 1978, 21/8, 1-3.

One index of the success of this workshop and of the interest in the products of this program is the fact that as a consequence of the Chicago workshop, the Airline Pilots Association organized in Washington D.C. a two day workshop on "Advances in workload study," that focused on the results of this program. This meeting, whose proceedings were also published (Proceedings of the Symposium on Man-System Interface: Advances in Workload Study. Air Line Pilots Association, Washington, D.C., 1978), attracted a large audience from DOD, the Aircraft industry and interested government agencies. The reception of the program's results was very favorable, and several ongoing projects had their inception in these two meetings.

As for technology assessment, the jury is still out. The results will emerge after current activities conducted in conjunction with the Air Force and the Navy can be evaluated. The scientific results reported by the investigators in this program are holding up very well under the usual scientific scrutiny. Whether the technology will indeed be available for use in "real-life" remains to be seen.

BIBLIOGRAPHY

A. Harvard University, "The Use of Electromyography to Implement a Silent, Fast Typewriter."

B. University of California at Los Angeles, "The Application of Pupillometry Towards the Estimation of Momentary Information Processing Load or Mental Effort Associated with Various Functions and Tasks."

Beatty, J. Pupil dilation as an index of workload. In Proceedings of the Symposium on Man-System Interface: Advances in Workload Study. Washington, D. C.: Air Line Pilots Association, 1978.

Beatty, J. Pupillometric and EEG indicators of operator workload. In F. Gomer (Ed.), Biocybernetics and man/machine systems. McDonnell Douglas, in press.

Ahern, S., & Beatty, J. Physiological signs of information processing vary with intelligence. UCLA Technical Report #17, 15 December 1978.

Beatty, J., & Wagoner, B. L. Activation and Signal Detection: A Pupillometric Analysis. Human Neurophysiology Laboratory Technical Report, 1 August 1977.

Beatty, J. Pupillometric Assessment of Decision Processes in the Detection of Weak Acoustic Signals in Noise. Human Neurophysiology Laboratory Technical Report, 1977.

C. University of California at Los Angeles, "Direct Brain-Computer Coupling via Brain Responses."

Vidal, J. J. Neurocybernetics and Man-machine Communication. Proceedings of the International Conference on Cybernetics and Society San Francisco, September, 1975, 421-442.

Vidal, J. J. Real-time detection of brain events in EEG. IEEE Proceedings, Special issue on biological signal processing and analysis, 1977, 65, 633-641.

Vidal, J. J. & Helfebein, E. D. H_____ transforms of event-related potentials: Toward an optimal re-expression of the data. Proceedings of the Nato Symposium on Event-Related Potentials in Man: Applications and Problems, Konstanz, Germany, August, 1978.

Hickman, R. A neurocybernetic approach to man-machine communication. Proceedings of the 16th San Diego Biomedical Symposium, San Diego, February, 1977.

D. University of Rochester, "Event-Related Brain Potential Correlates of Stimulus Meaning."

Chapman, R. M. Language and evoked potentials. In D. A. Otto (Ed.), Multidisciplinary Perspectives in Event-Related Brain Potential Research. U. S. Government Printing Office, WAshington, D. C. EPA-600/9-77-043, 1979, pp. 245-249.

Chapman, R.M. Methods of evoked-potential analysis in linguistic research, In D. A. Otto (Ed.), Multidisciplinary Perspectives in Event-Related Brain Potential Research. U. S. Government Printing Office, Washington, D. C., EPA-600/9-77-043, 1979, pp. 265-266.

E. University of Illinois, "The Vocabulary of Event-Related Brain Potentials and its Application in the Cockpit and CAI Environment."

Donchin, E. Measurement in AEP studies (opening remarks). In W. C. McCallum & J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, England, 1973. Bristol: John Wright and Sons, 1976, pp. 5-9.

Donchin, E., Johnson, R., Jr., Herning R., & Kutas, M. Covariation of the magnitude of the CNV & P300 as a function of the subject's task. In W. C. McCallum and J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, England, 1973. Bristol: John Wright and Sons, 1976, pp. 76-80.

Donchin, E., & Kutas, M. Preliminary observations on the effects of response parameters on pre-responsive potentials. In W. C. McCallum and J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on Event-Related Slow Potentials of the Brain. Bristol, England, 1973. Bristol: John Wright, 1976, pp. 108-110.

Donchin, E. (Ed.), The relationship between P300 and the CNV. A correspondence and an experimental report. In W. C. McCallum and J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on event-related slow potentials of the brain. Bristol: John Wright and Sons, 1976, pp. 216-234.

Wickens, C., Isreal, J., & Donchin, E. The event-related cortical potential as an index of task workload. In A. S. Neal & R. F. Palasek (Eds.), Proceedings of the Human Factors Society 21st Annual Meeting, San Francisco, October, 1977.

Kutas, M., & Donchin, E. Variations in the latency of P300 as a function of variations in semantic categorizations. In D. Otto (Ed.), Multidisciplinary perspectives in event-related brain potential research. EPA-600/9-77-043, Washington, D. C.: U.S. Government Printing Office, 1979, pp. 198-201.

Donchin, E. The use of the scalp distribution as a dependent variable in ERP studies. In D. Otto (Ed.), Multidisciplinary perspectives in event-related brain potential research. EPI-600/9-77-043, Washington, D. C., U. S. Government Printing Office, 1979, pp. 501-510.

Donchin, E., & Heffley, E. Multivariate analysis of event-related potential data: A tutorial review. In D. Otto (Ed.), Multidisciplinary perspectives in event-related brain potential research. EPO-600/9-77-043, Washington, D. C., U.S. Government Printing Office, 1979, pp. 555-572.

Squires, K. C., Wickens, C., Squires, N. K., & Donchin, E. Sequential dependencies of the waveform of the event-related potential: A preliminary report. In D. A. Otto (Ed.), Multidisciplinary perspectives in event-related brain potential research. EPA-6001-9-77-043, Washington, D. C., U.S. Government Printing Office, 1979, pp.

Donchin, E., & Isreal, J. B. Event-related potentials and psychological theory. In H. H. Kornhuber and L. Deecke (Eds.), Proceedings of the 5th International Symposium on Electrical Potentials Related to Motivation, Motor and Sensory Processes of the Brain. Amsterdam: Elsevier, in press.

F. Stanford Research Institute, "Inferring Words from Electrical Brain Activity."

Pinneo, L. R., Herron, J., & Rebert, C. S. Feasibility study for design of a biocybernetic communication system. Fifth semi-annual technical progress report. ARPA, February, 1975.

Pinneo, L. R., & Rebert, C. S. Feasibility study for design of a biocybernetic communication system. Sixth semi-annual technical progress report. ARPA, April, 1975.

Pinneo, L. R., Johnson, P., Herron, J., & Rebert, C. S. Feasibility study for design of a biocybernetic communication system. Final technical report. ARPA, August, 1975.

G. Stanford Research Institute, "The Use of Hemispheric Imbalances as an Indication of Cognitive Style and Cognitive Strategy."

Rebert, C. S. Electroencephalographic analysis of hemispheric dominance and performance. Final report. ARPA, August, 1976.

Rebert, C. S. Electroencephalographic analysis of hemispheric dominance and performance. First semi-annual technical progress report. ARPA. January, 1976

Chapman, R. M. Language and evoked potentials. In D. A. Otto (Ed.), Multidisciplinary Perspectives in Event-Related Brain Potential Research. U. S. Government Printing Office, Washington, D. C. EPA-600/9-77-043, 1979, pp. 245-249.

Chapman, R.M. Methods of evoked-potential analysis in linguistic research, In D. A. Otto (Ed.), Multidisciplinary Perspectives in Event-Related Brain Potential Research. U. S. Government Printing Office, Washington, D. C., EPA-600/9-77-043, 1979, pp. 265-266.

E. University of Illinois, "The Vocabulary of Event-Related Brain Potentials and its Application in the Cockpit and CAI Environment."

Donchin, E. Measurement in AEP studies (opening remarks). In W. C. McCallum & J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, England, 1973. Bristol: John Wright and Sons, 1976, pp. 5-9.

Donchin, E., Johnson, R., Jr., Herning R., & Kutas, M. Covariation of the magnitude of the CNV & P300 as a function of the subject's task. In W. C. McCallum and J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on Event-Related Slow Potentials of the Brain, Bristol, England, 1973. Bristol: John Wright and Sons, 1976, pp. 76-80.

Donchin, E., & Kutas, M. Preliminary observations on the effects of response parameters on pre-responsive potentials. In W. C. McCallum and J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on Event-Related Slow Potentials of the Brain. Bristol, England, 1973. Bristol: John Wright, 1976, pp. 108-110.

Donchin, E. (Ed.), The relationship between P300 and the CNV. A correspondence and an experimental report. In W. C. McCallum and J. R. Knott (Eds.), The responsive brain. Proceedings of the Third International Congress on event-related slow potentials of the brain. Bristol: John Wright and Sons, 1976, pp. 216-234.

Wickens, C. D., Isreal, J., McCarthy, G., Gopher, D., & Donchin, E. The use of event-related potentials in the enhancement of system performance. Proceedings 12th Annual Conference on Manual Control. NASA TM X-73, 170, 1976.

Wickens, C., Isreal, J., & Donchin, E. The event-related cortical potential as an index of task workload. In A. S. Neal & R. F. Palasek (Eds.), Proceedings of the Human Factors Society 21st Annual Meeting, San Francisco, October, 1977.

Kutas, M., & Donchin, E. Variations in the latency of P300 as a function of variations in semantic categorizations. In D. Otto (Ed.), Multidisciplinary perspectives in event-related brain potential research.

I. Massachusetts Institute of Technology, "The Utilization of Magnetoencephalography (MEG) as a Biocybernetics Channel."

Cuffin, B. N., & Cohen, D. Magnetic fields of a dipole in special volume conductor shapes. IEEE Transactions on Biomedical Engineering, Vol. BME-24, #4, July 1977, pp. 372-381.

DISTRIBUTION

Dr. Glenn Bryan
ONR
800 North Quincy Street
Arlington, VA 22217

Dr. Alfred Fregley
AFOSR/NL
Bldg. 410
Bolling Air Force Base
Washington, D.C. 20332

Dr. Mike Kaplan
ARI
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Harry O'Neil
ARI
5001 Eisenhower Avenue
Room #6W09
Alexandria, VA 22333

Dr. Robert Biersner
Naval Medical R&D Command
National Naval Medical Center
Building 142
Bethesda, MD 20014

Dr. Emanuel Donchin
University of Illinois
Dept. of Psychology 825
Champaign, IL 61820

Dr. Larry Pinneo
[redacted]

Dr. Jaques J. Vidal
3531 Boelter Hall
Univ. of Calif.-Los Angeles
Los Angeles, CA 90024

Dr. Robert Chapman
Department of Psychology
University of Rochester
Rochester, NY 14627

Dr. Laverne Johnson
U.S. Naval Health Research Center
Psychophysiology Division
San Diego, CA 92152

Dr. Jackson Beaty
Department of Psychology
University of California-Los Angeles
Los Angeles, CA 90024

Dr. Charles Rebert
Department of Psychology
SRI
Menlo Park, CA 90037

Dr. Gary Schwartz
210 Kirkland Hall
Yale University
New Haven, CT 06520

Dr. James Anliker
Department of Electrical Engineering
Stanford University
Stanford, CA 94305

Dr. Timothy J. Teyler
Department of Psychology
Harvard University
Cambridge, MA 02138

Dr. Richard Thompson
Department of Psychobiology
University of California, Irvine
Irvine, CA 92717

Dr. David Cohen
MIT
Cambridge, MA 02138

Dr. Christopher Wickens
University of Illinois
Department of Psychology
Champaign, IL 61820

Dr. Daniel Gopher
Department of Industrial Engineering
Technion, Haifa, Israel

Dr. Enoch Callaway
Langley Porter Institute
401 Parnasus Avenue
San Francisco, CA 94122

Dr. William R. Goff
Neuropsychology Laboratory
VA Hospital
West Haven, CT 06516

Dr. Donald B. Lindsley
Department of Psychology
Univ. of California-Los Angeles
Los Angeles, CA 90024

Dr. Michael Posner
Department of Psychology
University of Oregon
Eugene, OR 97403

Dr. Neville Moray
Department of Psychology
University of Stirling
Stirling, Scotland

Dr. Tom Sheridan
MIT
105 Mass. Avenue
Rm. 1-110
Cambridge, MA 02139

Dr. Donald Norman
Department of Psychology
University of California-San Diego
La Jolla, CA 92037

FISCAL SUMMARY

Program Title: Biocybernetics

ARPA Order	Line Number	Agent	Contractor, Contract No.	FY76	FY7T	FY77	FY78	FY79	Totals
3053	C21101	ONR	Univ. of Illinois N1476C0002	650	90	476	462	447	2125
3294	C12205	ONR	Univ. of Rochester N1477C0037	- -	- -	129	- -	- -	129
3306	C12204	ONR	UCLA N1477C0030	- -	- -	90	- -	- -	90
3330	C12202	ONR	Science Applications N1477C0107	- -	- -	185	- -	- -	185
3510	W17159	DSS-W	McDonnell Douglas MDA90378C0181	- -	- -	- -	150	60	210
			TOTALS	650	90	880	612	507	2739

Bud Durand
Program Management Officer
Date: 1 April 81